8. Paints, dips, fabric coatings, etc., are of little or no value in mitigating electrolysis, fabric coatings especially rather tending to increase than decrease the damage.

9. Better bonding of rails, introduction of insulating joints and like remedial measures have so far proven the most helpful in electrolysis mitigation.

10. Only perfectly insulated return circuits offer absolute immunity from stray current damage.

ECONOMICS OF BRIDGE DESIGN*

It has been found by experience that, for trusses with polygonal top chords, the economic depths, as far as weight of metal is concerned, are generally much greater than certain important conditions will permit to be used. For instance, especially in single-track, pin-connected bridges, after a certain truss depth is exceeded, the overturning effect of the wind-pressure is so great as to reduce the dead-load tension on the windward bottom chord to such an extent that the compression from the wind load carried by the lower lateral system causes reversion of stress, and such reversion eye-bars are not adapted to withstand. A very deep truss requires an expensive traveler, and decreasing the theoretically economic depth increases the weight but slightly; hence it is really economical to reduce the depth of both truss and traveler. Again, the total cost of a structure does not vary directly as the total weight of metal, for the reason that an increase in the section area of a piece adds nothing to the cost of its manufacture, and but little to the cost of erection; consequently it is only for raw material and freight that the expense is really augmented. Hence it is generally best to use truss depths considerably less than those which would require the minimum amount of metal. For parallel chords, the theoretically economic truss depths vary from one-fifth of the span for spans of 100 ft. to about one-sixth of the span for spans of 200 ft.; but for modern single-track railway through-bridges the least allowable truss depth is about 30 ft., unless suspended floor-beams be used, a detail which very properly has gone out of fashion.

In designing plate-girders, if one will adopt such a depth as will make the total weight of the web with its splice-plates and stiffening angles about equal to the weight of the flanges, he will obtain an economically designed girder, and a deep and stiff one. For long spans, however, this arrangement would make the girders so deep as to become clumsy and expensive to handle; consequently, when a span exceeds about 40 ft., the amount of metal in the flanges should be a little greater than that in the web; and the more the span exceeds 40 ft. the greater should be the relative amount of metal in the flanges.

A rather lengthy mathematical investigation for plate-girders, based upon fairly accurate assumptions, proves that the theoretical maximum of economy exists when the gross areas of flanges and of web at mid-span are equal—a condition readily remembered. Although this is the theoretically correct criterion for economy, if it be applied to any particular case, it will generally be found that the resulting web depth is so excessive as to cause one or more of the following modifications in construction, as compared with the depth which would make the total weight of the flanges equal to the total weight of the web with all its details:

(*a*) An additional splice or two in the web, or else a slightly increased pound price for the large plates. (*b*) Larger outstanding legs for all stiffening angles. (*c*) Reduction in the number of cover plates. (*d*) Narrowing of flange angles and necessitating thereby either an additional bracing frame or an increase in sectional area of the compression flange, in order to compensate for the greater ratio of unsupported length to width. (*e*) Possibly thickening of web because of its greater depth. (*f*) Possible encroachment on under-clearance in deck spans, or raising of grade to avoid the same. (*g*) Possible difficulty in fabrication or shipment in case of long or heavy girders because of excessive depth.

Any of these changes would be likely so to upset the economics of the case as to cause a material decrease in the theoretically best depth, hence it is generally advisable to adhere to the rule previously given; but there are occasionally cases where a saving of metal may be effected by making the web depth somewhat smaller, when by so doing a web-splice may be avoided or lighter stiffening angles may be adopted. It should be borne in mind that there is quite a range in web-depths over which the theoretic minimum weight is about constant, unless the thickness of the shallower web must be increased on account of shear; hence one may often vary the dimensions of a plate-girder materially without affecting greatly the matter of economics.

Concerning economic panel lengths, it is safe to make the following statement: Within the limit set by good judgment and one's inherent sense of fitness, the longer the panel the greater the economy of material in the superstructure. Of course, when one goes such an extent as to use a 30-ft. panel in an ordinary single-track railway bridge he exceeds the limits referred to, because the lateral diagonals become too long, and their inclination to the chords becomes too flat for rigidity. Again, an extremely long panel might sometimes cause the truss diagonals to have an unsightly appearance because of their small inclination to the horizontal.

There is another mathematical investigation which is of practical value. It relates to the economic lengths of spans. The principle is that "for any crossing the greatest economy will be attained when the cost per lineal foot of the substructure is equal to the cost per lineal foot of the trusses and lateral systems." The old practice was to make for economy the cost of a pier equal to the cost of the span that it supports, or, more properly, equal to one-half of the cost of the two spans that it helps to support. Is not the difference between these two methods perfectly plain? In one the cost of the pier is made equal to the cost of the trusses and laterals, and in the other it is made equal to the cost of the trusses, laterals and floor system. When one considers that the cost of the floor system is sometimes almost as great as one-half of the total cost of the superstructure, he will recognize how faulty the old method was.

The demonstration proves that in any layout of spans, with the conditions assumed, the greatest economy will be attained when the cost of the substructure per lineal foot of bridge is equal to the cost per lineal foot of the trusses and lateral systems. Of course, no such condition as a bridge of indefinite extent ever exists, nor is the bed-rock often level over the whole crossing; nevertheless, the principle can be applied to each pier and the two spans that it helps to support by making the cost of the pier equal to one-half of the total cost of the trusses and laterals of the said two spans.

*From a lecture by Dr. J. A. L. Waddell at the School of Engineering of the University of Kansas.